Ship Platform Collision Analysis and Damage Modelling

by

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Dissertation submitted in partial fulfilment of

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(Civil Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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(CIVIL ENGINEERING)

Approved by,

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(Dr. Zubair Imam Syed)

UNIVERSITI TEKNOLOGI PETRONAS.

TRONOH, PERAK

January 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

ZARAH HANIMAH NOORAZYZE

ABSTRACT

Collision between vessel and offshore platform usually result in damages to both of the structures. An incident may happen as the vessel losing its capability to control it movements due to environmental, electrical or mechanical reasons of the vessel. The effected members may experience large deformation damage causing the members to buckle cracks or distort which eventually may lead to progressive collapse of the platform. Even though the accidents related to the collision have been seen reduces to date, the accidents still remain as a highly risks event. There is a clear gap in knowledge in analysis of the ship-platform collision event to establish the significance and severity of these events. Therefore, a study on Ship-Platform collision was conducted to present the risk and frequency of a collision event to occur to an offshore platform. Available recorded data on ship-platform collision were utilised to identify the frequency and severity of these events.

This project also investigated the damage magnitude and severity of a collision event on the jacket lag of an offshore platform. Non-linear finite element method was used to study the damage magnitude and other parameters associated with a collision event. The simulated FEM model was employed to perform the parametric study to explore the influence of different parameters associated with a ship impact.

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In the name of Allah, The Beneficent, The Merciful.

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Abbreviation & Nomenclature

1.	ABS	American Bureau of Shipping
2.	ANSYS	Engineering Simulation Software
3.	API	American Petroleum Institute
4.	FEA	Finite Element Analysis
5.	FEM	Finite Element Method
6.	FPSO	Floating Production, Storage, and Offloading
7.	HSE	Health and Safety Executive

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND STUDY

The first oil offshore platform was built near Baku in Soviet Union in 1951. Since then, the offshore building started to advance along and inside the ocean. However, these structures are vulnerable to damage caused by dropping objects, corrosion and contacts from vessels. Not only these platform need to endure normal loads, it also subjected to other loads such as blast loading, and sometimes the platform receive an unexpected load such as collision with ships.

For the few decades, the collision accidents has been recorded and showed it can be results to damaging the members of the structure platform and potentially affecting the structure integrity and safety. Answering this problem a mitigation method can be proposed. Thus, revealing the extent research of ship platform collision and its effects of the accident.

Ship platform collision poses several problems and many discussion and argument against such accidents have been presented over the years. The major problem is all the accidents should have been reported and recorded to be analysed and reassess to mitigate the damages to the platform structure. The damage will then be classified into different damage severity categories. Generally, the damage severity is divided into six categories which is:

a) Severe – the damage is affecting the integrity of the structure and required immediate repair.
b) Moderate – damage member must be repaired in six months' time or later than that.
c) Minor – damage not affecting the integrity of the installation.
d) None – no damage occurred.
e) Unspecified – incident happens but was not specified in reports.
f) Not applicable – report of incident which was not applicable to installation's structure

The severe and moderate categories have been considered as may endanger the life and health of people living on the platform structure or poses threats to the structures, as there are evidence that the structure experienced cracks and other major problem. However, the other categories are seldom reported as it has been considered as not serious threat. Therefore, it can be found that the reported accidents have lower historical data than the severe and moderate categories. Thus, more effort is focussing on the deformation during and after the collision.

Before any construction on the deformation accident, it is important that the impact value generated is determined. It starts with the identification of the possible parameters involve in the accident. This parameter indicates the ship malfunctioning, weather, environment, human fatigue, etc. The characteristic of the parameters is then classified under various loading condition to configure mitigating and engineering solution.

Apart from the collision issues, the parameters involve should be studied deeper. Although little is known about the effect of specific parameter in the collision, such information may have some values in developing a structure damage modelling. This model is a step forward for analysis and assessment ship platform collision.

1.2 PROBLEM STATEMENT

The main problem for this project is to determine the collision point that is capable to show the critical damage impact to the structure modelling. As there are many parameters that need to be considered such as, approach angle that can be made during the collision, estimating the velocity of the impact, material properties of the structural components and environmental condition that reflects during the event. Since the optimized parameters of effecting the collision event and the effects on the platform structure have not been explored deeply. A novel approach determines the severity of damage due to the parameters has been proposed. However, which parameter that will give the most impact still remains unknown.

1.3 OBJECTIVE OF STUDY

1. To conduct risk assessment based on available recorded data.
2. To simulate ship platform collision.
3. To investigate damage pattern of the jacket leg for accidental impact.

1.4 SCOPE OF STUDY

The scope of study in this project will be reflected based on the analysis of the parameters that can give a variety of data on the damage severity that it can affect the offshore structure members. The data will be recorded and the time frame to conduct this project is approximately less than 8 months. However, because of the parameters given is too vast, only few promising parameter will be selected. The project is expected to be completed within the time period allocated.

1.5 RELEVANCY OF THE PROJECT

To perform an analysis of the ship platform collision, the author has to review historical data of the collision. The data of this project will give a better understanding of risk associated with ship platform collision. From the analysis, the author can move on to damage modelling assessment. The modelling is done by using FEM simulation. From the simulation, the author develops a better understanding of the damage patterns and structural responses of offshore platform.

1.6 FEASIBILITY OF THE PROJECT (SCOPE AND TIME)

Non-linear simulation will be used in this project that will give the author a better understanding of the risk accidental with ship platform collision. With that understanding, the author will be able to develop an analysis of the damage pattern and standard response of the offshore platform.

CHAPTER 2

LITERATURE REVIEW

A collision between ship and offshore platform has been recognised as one of the major hazard in offshore platform studies. A survey of this event has been conducted since the period of 1970 till the present time. The statistics shows that the collisions events has contribute more significant risk situation to its surrounding than other risk pointed out. Approximately 10 percentage of the annual damage cost for an offshore installation is related to collisions. (DNV Technica, 1995). Although the consequences of most offshore collisions have been minor to date, a ship collision is potentially an accident of highly serious character. (HSE, 2003). Therefore, an assessment is needed to evaluate every aspect the damage poses to the platform structure due to the collision.

Accident events can be described as unintentionally occurrence that happen during unspecified time at unspecified location. In offshore platform, accidental loading have to be considered in design. As cited by Yong Bai (2003), accidental load can be refers to unexpected load that may result in a catastrophe causing negative economic impact, environmental, material consequences and the loss of human life. The accidental loading objective is to measure the magnitude of the damage that can be reflected by the structural design, and to confirm the frequency of the accident will not go higher in terms of the worker health and safety conditions, the impact on the environments or the damage it can cause on the facility.

The accident scenarios can be identified by three approaches. First approach is from the statistic from previous data or known as historical data. When the first approach is not available, the second approach can be used. The expert opinion is a considered as valuable findings, as it undergoes successful and unsuccessful experiments and experiences. Then the most important risk analysis can be done as the third approach, the risk analysis approach has emerged as a very powerful tool. (Wang, G. Jiang, D. & Shin, Y., 2003).

It has been recorded in historical data from HSE 2003 that the collision between the supply vessels with the platform is the highest than any other ship as much 63.4%, stand-by vessels with 15.6%, other attendant by 13.3%, passing vessel with the lowest rate of 1.4% and unspecified vessels with 6.3%. It can be assumed that the collision by the supply vessels is the highest because the vessels regularly visit the platform to supply material for the workers and infrastructure, but in most cases the consequences involved are small. (Larsen, C. M. & Engseth, A. G., 1978).

A hazard risk assessment method for the oil and gas industry is used to design the accidental loading .As the design includes the determination of design loads based on risk consideration, prediction of structural response using rigid-plastic analytical formulation and/or non-linear Finite Element Method (FEM) and selection of risk-based acceptance criteria (Yong Bai, 2003). The accidental loading assumed that the structure is in plastic behaviour rather than in elastic regime, in sense that the sheer magnitude of the accident makes requiring an elastic response impractical in most cases given the low possibility of the event occurring.

To estimate collision frequencies, most of the risk models are divided into two. The first step is to begin the potential collision risk is determined without considering any risk mitigation options, as rooted in an approach from 1974. (Friis-

Hansen & Simonsen, 2002). And next step is to assess the effects from the collision and how to mitigate the risk for the accidents. There are many different models that are used to estimate the collision frequencies, and the models used almost the same approach to estimate the probability of the collisions. However, these models are based on assumption given that the results never had been proved due to the lack of data (DNV).

The risk assessment is divided into two phases, the preliminary accidental hazard risk assessment and detailed risk assessment. In primary accidental hazard risk assessment, there are four criteria need to find out. Firstly, the definition of accident acceptance criteria where it needs to define the criteria of each accident type based on codes, regulation and guidance given. It should be able to define potential damage that the structure is impacted to. Next is accidental loading hazard identification, it is a process to determine the hazard identification method based on the API codes by the qualified staff as it involves the identification of hazard over the life span of the facility.

Third criteria is the preliminary accident assessment, this criteria have to evaluate the probability and effects related to events the second criteria mentioned before. And lastly, the preliminary risk evaluation where it has to identify the aspect need to look at based on the preliminary accident assessment. The result of the evaluation will be the detailed description of the accident and the mitigation required. The second phase of the risk assessment is divided into an initial event screening from the preliminary accident assessment and a refined hazard assessment.

For the analysis of probability of ship-platform collision, an approach based on the computer simulation techniques is used. This method will give a summary of results regarding the collision. The commercial software is based on finite element theory, where the designer has to input different and various data such as different element types, boundary conditions and other relevant data. Numerical simulation analysis is carried out to inversely identify the impact load characteristics according to the detected damage on the impacted member. (Jin. W. L. Song, J. Gong, S. F. & Lu, Y., 2005). The result of the simulation then can be used to analysis either to strengthen the structure, material strength or by adding additional reinforcement. In sense, the accuracy of the simulation is increases when the number of data is defined but it required cost and its time consuming. Therefore, the designer has to consider the limits of the model and the probability of the accuracy of the analysis result.

According to Kjeoy, H and Amdahl, J. (1979), there are three vessel orientations normally considered in collision studies. There are head-on collision, side-on collision and stern collision. The orientation of the vessel is considered as one of the most important parameter as it will influence both the added mass and collision velocity. The difference in stiffness and strength of a vessel's bow, stern and side can affect the amount of damage caused to platform jacket. The load indentation relationships for typical supply vessels indicate that a ship's stern is its stiffest section, and therefore the part liable to cause most damage to an installation in a collision (Kenny, J.P, 1988). Vessel orientation collision can be shown from figure 2.0 to figure 2.2 below.

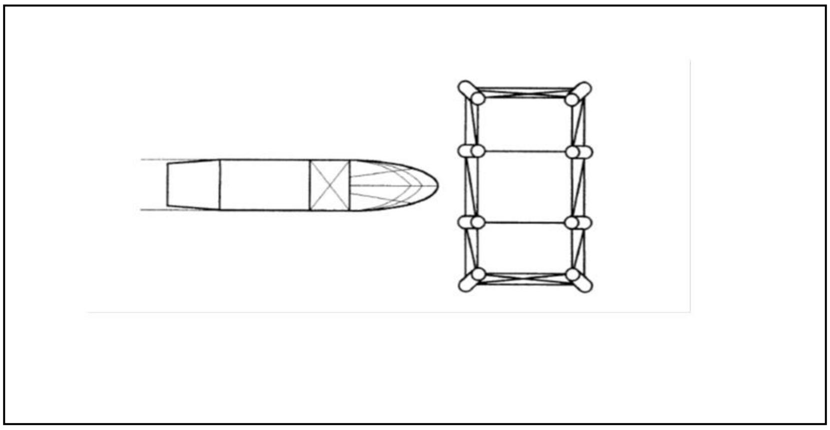

Figure 2.0: Head-on collision between vessel and jacket leg.

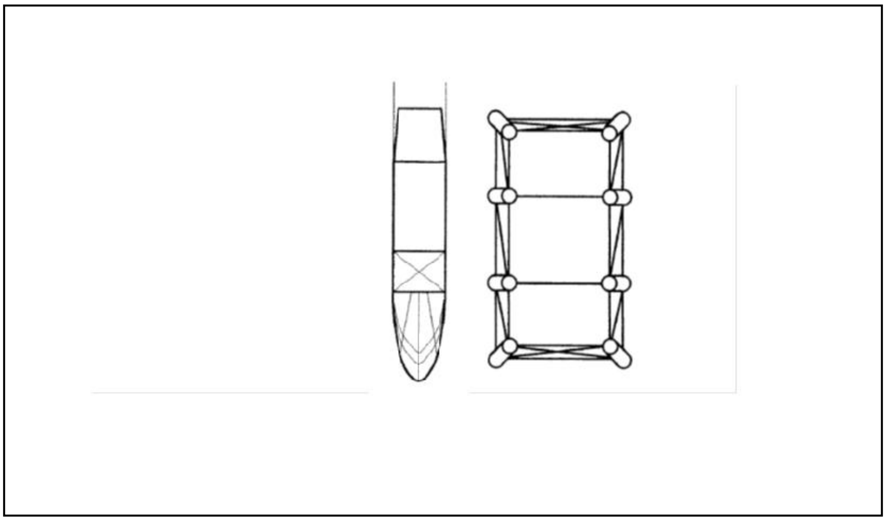

Figure 2.1: Side-on collision between vessel and jacket leg.

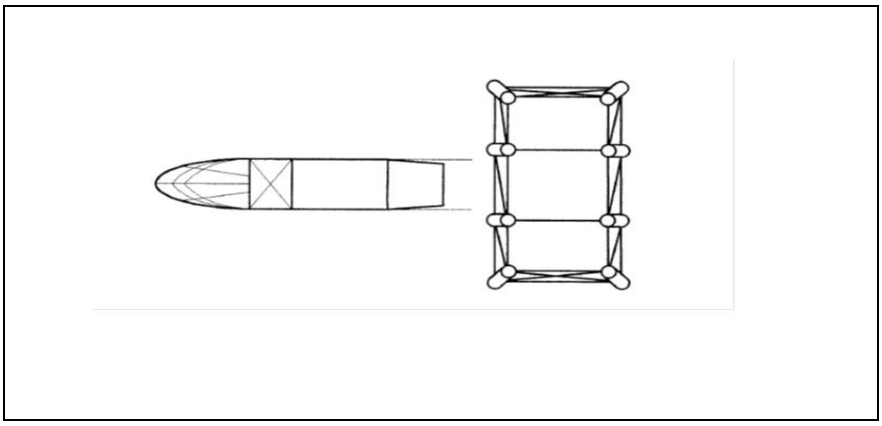

Figure 2.2: Stern collision between vessel and jacket leg.

According to the statistic, most of the incidents of passing vessel collision in the department of energy accident records were bow collision Kjeoy, H and Amdahl, J. (1979). The bow of the ship can ram the bracing or member of the steel structure. However, from the investigation of NMI LTD the severity of collision of attendant vessels with offshore platform discover stern collision occur with much higher frequency than head-on or side-on collision for fixed platform (Kjeoy, H and Amdahl, J., 1979).

There are many factors or parameters causing the collision event that has been studied as it is important to realize the probability as well as the effect it can reflect. Among the many factors are, the type of the vessel, the speed of the vessel, the point where the ship hits, the environment effect, traffic monitoring, mooring equipment etc. However, the type of vessel is left out as the collision risk frequency is not based on the vessel type but rather to the way the vessel traffic travel. The collision risk frequency calculation mainly based on the number of vessels that pass the location annually, the probability of the vessel heading towards the platform, the probability that avoidance planning was not used during voyage planning, a watch-keeping failure occurs and the vessel is not alerted in time by the platform or its standby vessel (Flohberger M.L., 2010).

The effect of the collision in worse scenario is it can lead to a total collapse of the structure resulting fatalities, environmental damages and high economic costs. The reports for the accident should have the following data; the date of the accident, type of installation (eg. Semi-submersibles, jack-up platform, etc), installation location, the type and size of the impacting vessel, prime cause of the incident, operating circumstances, the damage to the installation, type of repair required for the installation. And there are possibilities that some of the detail is lost during the data extraction but the general observations from the incident are matter the most.

The extraction data is important tool as the next step is to classify the accident into one of the six categories of the installation damage class. There are not specified, fenders, no damage, minor, moderate and severe categories. Not specified category is where the report of the incident is not reported and does not affect the infrastructure. The incident where damage is occurred but was not reported is in fender category. In minor category, the damage involves in denting or bending of the structure but pose no effect in the integrity of the installation. Next category is the moderate category, where the repair on the structure is required as the structure of the member is fracture, bend and/or dents involve. The repair period is up to six month or longer. And lastly the severe class, where the damage is greatly affect the structure and required immediate repair. The energy struck the installation was greater than 0.5 MJ. (Kenny J.P., 1988).

The ship collision assessment problem can be separated into two distinct mechanisms: external and internal mechanics (ABS, 2013). The external mechanics will be able to develop a data and information that gain from the motions of the facility and the vessel due to the collision event. Whilst, the internal mechanics will be focus more on the structural failures of the bodies. Assumption based on these two mechanism, a strain energy can be develops during the collision via structural deformation. There are three methods to determine the strain energy. Method A will be assumed that the kinetic energy transformation is determined for by facility deformation. Method B required two different analyses between the rigid body impacts the facility and colliding vessel. And Method C use computation to calculate the strain energy that develop and determine the probability of the impact. Between these three methods, method A is the most reliable methods to determine the strain energy and Method C is the least conservative and requires high cost.

In a Summary, by going through the literature review many important details have been recorded. The ship platform collision has been a major case study for a long time and there have been lot of studies regarding this incident. There are many parameter assumed to be involve during the accidents and the data from the accident have been recorded in historical table. From the table, it shows that the supply vessel is the largest contributor for the collision happened. The damage to the infrastructure is then classified into six different classes from non-applicable to severe class. It can be assume that the minor damage is usually neglected or does not been informed to be recorded hence showing the moderate, major and severe class to be the biggest contributor. There are many simulations or model is used for this study, FEM is among it. By collecting all these details, a proper research can be done by the author in the near future.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter outlines on the data analysis and collision modelling to achieve the desired objectives of the research. Part of the research focuses on the analysis of available recorded data on ship-platform collision and the other part of the research focuses on the finite element modelling of ship impact on jacket legs to present the possible damage patterns.

Information on the frequency of collision and quantification of damage has the potential to assist the design and maintenance engineers to perform more effective design and appropriate maintenance.

3.1.1 Data Analysis and Risk Prediction

Under this study the extensive data recorded by Health & Safety Executive of United Kingdom (HSE, 2003) is used. This data base contains a significant amount of collision events recorded between 1975 till 2001. The available collision incident records are used in this study to conduct statistical analysis of probability of ship-platform collision also to predict the frequency of level of damage according to the damage levels defined by HSE.

3.1.2 Numerical Modelling of Ship-Platform Impact

A broad range of issues related to collisions has been studied. Therefore the first methodology of this project is to reviews the related research and summarizes the findings. These will helps in surveying the publication that may suited into the framework to analyse the available data on ship platform collision analysis and helps find the probability of the incident on damaged platform.

The second methodology provides a structured approach to determine the valid modelling techniques, element and material models, and model parameter values for modelling ship collision using ANSYS software, Finite Element Analysis (FEA). FEA is the modelling of products and systems in a virtual environment, for the purpose of finding and solving potential structural or performance issues. It performs a fully explicit dynamic analysis and is very non-linear with multiple point contact and rupture. FE method requires particular variable such as element type, mesh size, boundary condition, contact type and other material properties. This will help identifies variable values that provide result consistent with the test result.

Thus from the results of the modelling simulation, analysis can be made and compared with the findings from the recorded data obtained. By comparing the results, a discussion and conclusion can be made.

Phase / Week	FYP 2														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
laboratory data simulation analysis and theoretical calculation work															
Submission of progress report															
Project work continues															
Pre-SEDEX															
Submission of draft report															
Submission of dissertation (soft bound)															
Submission of technical paper															
Oral presentation															
Submission of dissertation (hard bound)															

Table 3.1.0: Gantt chart of the project activities.

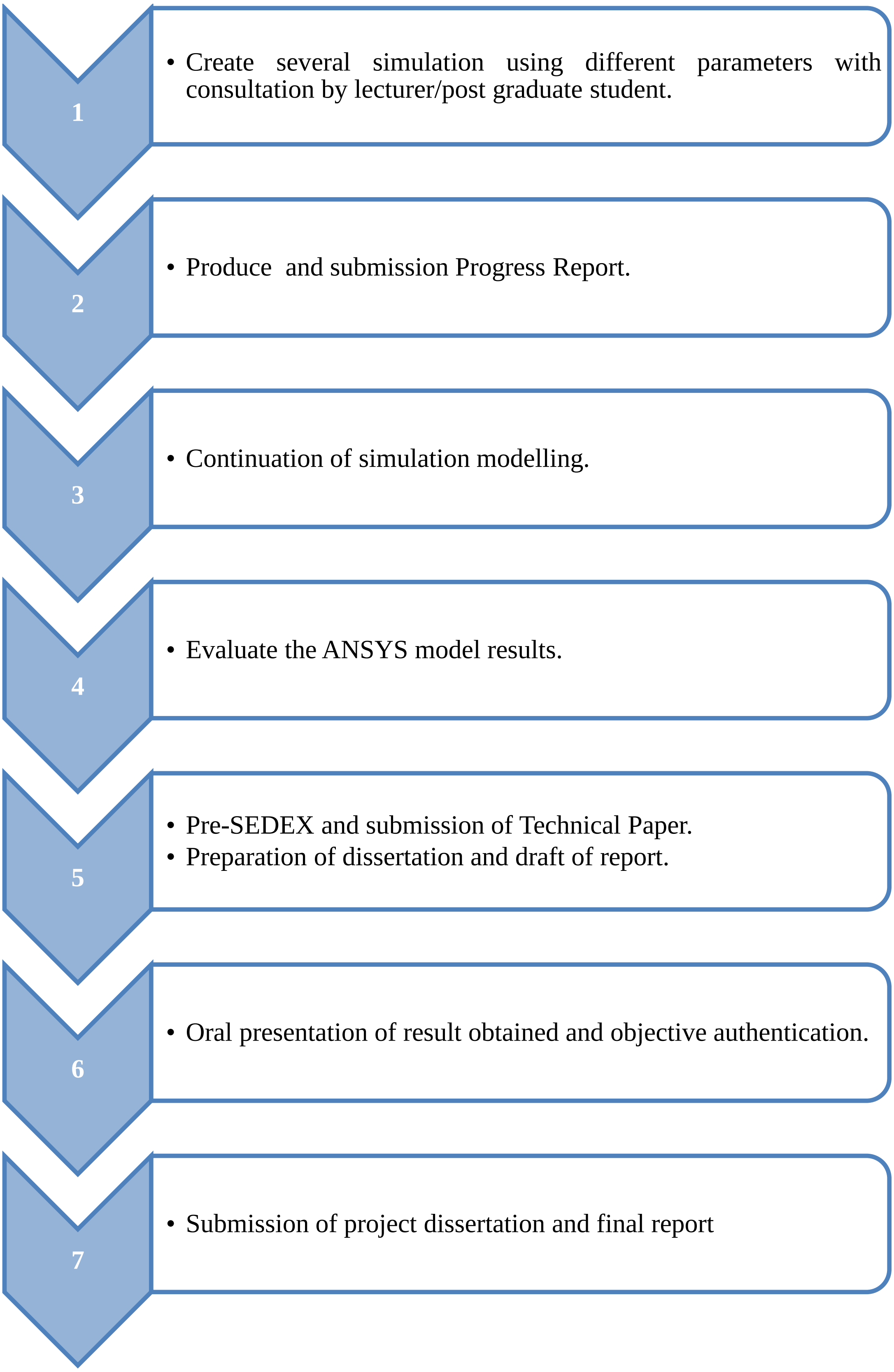

Figure 3.1.1: Project activities for FYP II

Key Milestone

Project Activities	2013			
	September	October	November	December
Continuation model simulation				
Submission of progress report				
Continuation model simulation				
Pre-SEDEX				
Submission of draft report				
Submission of dissertation (soft bound)				
Submission of technical paper				
Oral Presentation				
Submission of project dissertation (hard bound)				

Table 3.1.1: Key Milestone

Tools

The software that has been used and will be used for the project is:

No	Software	Description
1	Microsoft Office -Microsoft Word -Microsoft Excel	Documentation of the project work Producing data gathering
2	ANSYS software/ FEM	To do simulation solution that a design process is requires.

Table 3.1.2: Table of software

3.2 ANALYSIS METHOD

Accident event can be defines to be considered in design, usually it can be determined through three approaches:

- Statistic from historical data.
- Expert opinion
- Risk analysis

The historical data also known as available recorded data is the most reliable sources for identifying typical and critical accident cases, however it lacks of inconsistencies and the data may not thoroughly complete. Still, a major effort has been put into to build up a database of accidents and collision. However, by adding expert opinion depending on the situation, the parameter involving in the collision event can be analyses almost thoroughly, even though the opinion is based on successful and unsuccessful experiences or experiments. From expert opinion, it can point out many parameters that may involve in the accident such as the ship speed, loading condition, collision location and etc, usually the expert opinion is obtain from public domain as it is viewed as significant and should take accounted.

From the parameter pointed out from the historical data and expert opinion, a risk analysis can be made by identifies expected hazards. The parameter that can be studied will be involved with striking ship such as the impact speed of the vessel, vessel orientation. While for the jacket leg of the platform will includes the diameter and thickness of the column, by combining the parameters a damage structure can be obtained. However, because of the time constrain the orientation of the jacket leg will not be studied and even though Kang. H, Wei. J, Yi. L, mention that shuttle tanker has different bow type and can cause different structure damage when compare with other vessel, different type of vessel with differ dimension will not be studied in the modelling part rather the model vessel will be fix as a representative of an actual vessel. Figure 3.2.0 to 3.2.2 is data extracted from HSE database.

Year	Attendant Vessels	Passing vessels	Unspecified vessels
1975	7	0	4
1976	16	0	0
1977	18	0	4
1978	19	0	1
1979	30	0	1
1980	24	0	7
1981	34	1	3
1982	27	0	2
1983	26	1	1
1984	17	2	0
1985	20	1	1
1986	15	0	4
1987	8	0	0
1988	8	2	0
1989	22	0	0
1990	29	0	1
1991	27	0	0
1992	39	0	0
1993	22	0	0
1994	21	0	0
1995	13	1	0
1996	9	0	1
1997	14	0	4
1998	16	0	1
1999	15	0	0
2000	12	0	0
2001	6	0	0
TOTAL	**514**	**8**	**35**
TOTAL %	**92.28**	**1.44**	**6.28**

Table 3.2.0: Analysis data based on the specified vessel

	Collision Vessel Type					
Year	**Supply Vessel**	**Stand-by vessels**	**Other attendant**	**Passing vessels**	**Unspecified vessels**	**TOTAL**
1975	7	0	0	0	4	**11**
1976	13	1	2	0	0	**16**
1977	12	3	3	0	4	**22**
1978	19	0	0	0	1	**20**
1979	16	7	7	0	1	**31**
1980	20	0	4	0	7	**31**
1981	26	4	4	1	3	**38**
1982	21	4	2	0	2	**29**
1983	20	1	5	1	1	**28**
1984	10	2	5	2	0	**19**
1985	9	5	6	1	1	**22**
1986	12	1	2	0	4	**19**
1987	4	4	0	0	0	**8**
1988	5	2	1	2	0	**10**
1989	12	7	3	0	0	**22**
1990	17	11	1	0	1	**30**
1991	21	4	2	0	0	**27**
1992	29	7	3	0	0	**39**
1993	16	4	2	0	0	**22**
1994	13	5	3	0	0	**21**
1995	6	2	5	1	0	**14**
1996	7	1	1	0	1	**10**
1997	7	4	3	0	4	**18**
1998	10	1	5	0	1	**17**
1999	12	2	1	0	0	**15**
2000	8	1	3	0	0	**12**
2001	1	4	1	0	0	**6**
TOTAL	**353**	**87**	**74**	**8**	**35**	**557**
	63.38	**15.62**	**13.29**	**1.44**	**6.28**	**100.00**

Table 3.2.1: A data of reported collision based on the specific type of vessel.

	Damage Class						
Year	**None**	**Minor**	**Moderate**	**Severe**	**Unspecified**	**Not Applicable**	**Total**
1975	0	6	4	1	0	0	**11**
1976	2	12	2	0	0	0	**16**
1977	0	13	7	2	0	0	**22**
1978	1	12	7	0	0	0	**20**
1979	5	19	6	0	1	0	**31**
1980	4	13	9	4	1	0	**31**
1981	6	27	3	1	1	0	**38**
1982	8	14	7	0	0	0	**29**
1983	8	16	3	1	0	0	**28**
1984	4	9	5	0	1	0	**19**
1985	4	11	1	4	2	0	**22**
1986	5	9	4	0	1	0	**19**
1987	1	6	0	0	1	0	**8**
1988	2	7	0	1	0	0	**10**
1989	2	18	1	0	1	0	**22**
1990	5	19	3	1	1	1	**30**
1991	6	15	2	1	3	0	**27**
1992	5	28	2	1	3	0	**39**
1993	5	14	1	0	2	0	**22**
1994	6	10	0	0	5	0	**21**
1995	4	4	0	0	6	0	**14**
1996	2	6	1	0	1	0	**10**
1997	1	9	1	0	7	0	**18**
1998	0	7	0	0	10	0	**17**
1999	5	7	0	0	3	0	**15**
2000	1	8	0	0	3	0	**12**
2001	1	3	0	0	2	0	**6**
Total	**93**	**322**	**69**	**17**	**55**	**1**	**557**
	16.70	**57.81**	**12.39**	**3.05**	**9.87**	**0.18**	**100**

Table 3.2.2: A range of damage severity data from 1985 till 2001

In this project, analysis data will focussed on the damaged of the jacket leg made by the collision accident. The result of the analysis will be very helpful in finding the critical accident scenarios that in the future mitigation action can be made to enhance the strength of the jacket leg or to minimize the accident scenario.

3.3 NUMERICAL MODELLING OF SHIP IMPACT ON JACKET LEG

Finite element analysis (FEA) is a simulation software that shows or predict the designed product will reacts to real-world forces, vibration, heat, impact and other physical effects. FEA works by breaking down a real object into a large number of finite elements, and mathematical equations that help predict the behaviour of each element and lastly the computer will adds up all the individual behaviours to predict the results or effects to the actual object. To ensure that the design will be able to perform to specification prior to manufacturing, FE model can be created using one-dimensional (1D beam), two-dimensional (2D shell) or three-dimensional (3D solid) elements to evaluate different designs and materials, predict and improve product performance and reliability.

3.3.1 Material properties

From the data gathering and analysis, there are three material types were found in the ANSYS suitable or necessary for ship platform collision:

a) Elastic/plastic isotropic with piecewise linear plasticity – this material allows strain rate effects and complete material fracture. The ship will be modelled using this material.
b) Elastic/plastic isotropic with kinematic plastic hardening – this material type have "No Fracture" behaviour in its stress-strain curve to avoid the model elements away from damaged areas must remain intact for model integrity.
c) Rigid – this is used in rigid wall or a rigid bow of the ship. Rigid elements are bypassed in deformation processing and are very time efficient (Brown, A. J. , 2001)

The meshing in the simulation process is one of the important parts as it affects the accuracy, convergence and speed of the solution. Using the Sweep Method, a sweep mesh that can represent any arbitrary cross-section through the body is used and to make it more accurate, the element size and the number of divisions is specified as shown in figure 3.3.0 below.

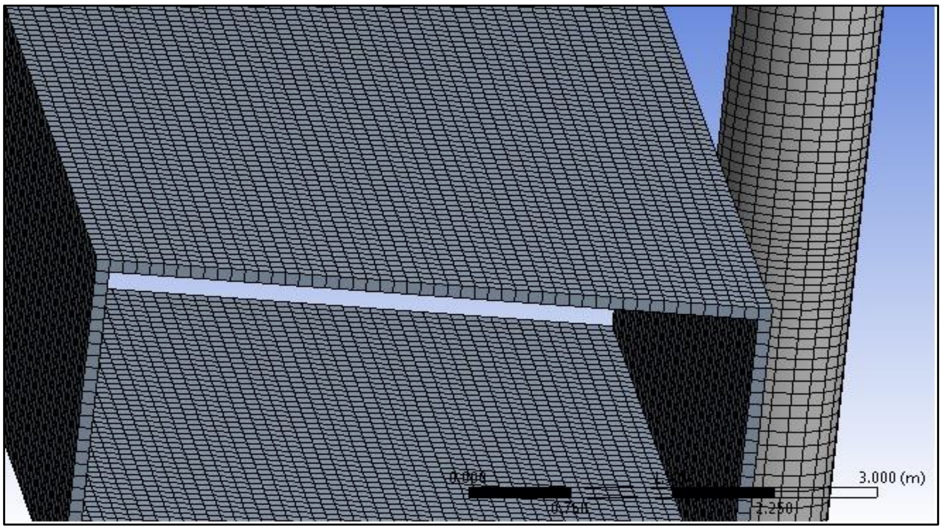

Figure 3.3.0: Mesh of the model.

3.3.2 Location of Impact

The vessel model is considered to hit the jacket leg on the middle. The impact location is shown in figure 3.3.1

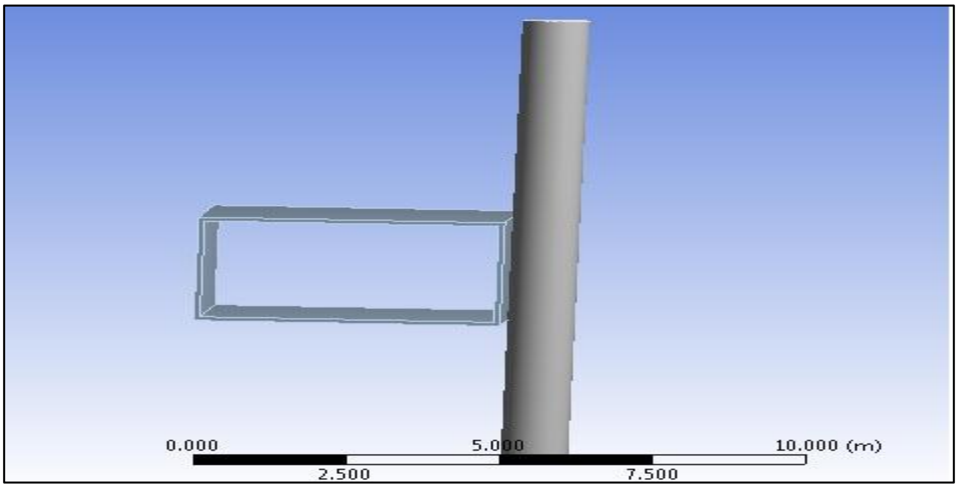

Figure 3.3.1: Location of vessel impacted on the jacket leg.

3.3.3 Vessel Model

Length	56 m (neglected)
Beam	8.2 m (neglected)
Draft	2.8 m

Table 3.3.0: Vessel model dimension.

The dimensions of the vessel model as shown in Table 3.3.0 are considered sufficient to get good results in impact analyses involving the jacket leg. The geometry was simplified in the modelling process. A square cut-out with approximately the same height and thickness is used while ignoring the length and beam of the ship to reduce computational time. The vessel used two different square shape impacted to the jacket leg as showed in figure 3.2.2.

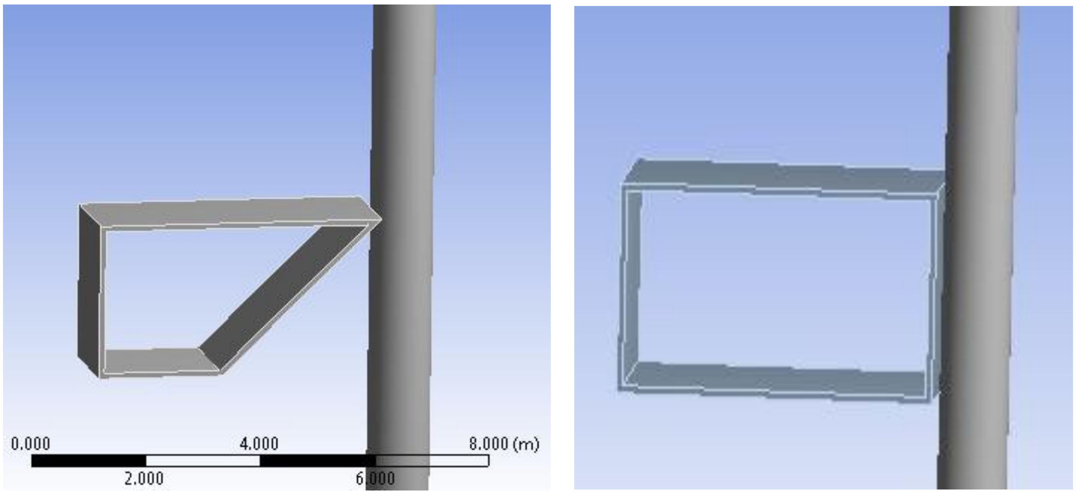

Figure 3.2.2: Two vessel orientation model. Head-on (left) and side-on (right)

A) Material Properties

For this project, the vessel is modelled using the same properties as shown in the table 3.3.1 below, however the density of the vessel is varied for each three analysis. The vessel will use elastic/plastic isotropic with kinematic plastic hardening.

Young's Module, E	2×10^{11} Pa
Yield Strength, σ_y	5.16×10^8 Pa
Density, ρ	15000 kg/m^3 30000 kg/m^3 40000 kg/m^3
Poisson's Ratio, μ	0.3

Table 3.3.1: Vessel material properties

The model is using a rigid material where the vessel is not allowed to deform or dissipate impact energy.

B) Mesh and Elements

The general size of the elements of the ship model is 0.2 m. The model is meshed in this way to see the important structure deformation characteristics. The figure showed the mesh used in the modelling.

C) Boundary conditions

The model is given two sets of boundary condition. The first condition is the model is restricted to motion only in the global x-direction. This will ensure that the model will hits the jacket leg as desired. The second condition is prescribing constant impact velocities of 1m/s, 2m/s and 4m/s with the increase of impact speed it is expected the collision is will be more severe. As cited by Kang. H, Wei. J, Yi. L, March 2013 the increase of impact speed will lead to more deformation on collision area, together with more impact energy.

D) Vessel orientation

There are three vessel orientations can be considered as a representative scenario in this project, there are head-on, stern-on and sideways-on. Accounting the sea environment and draught of the vessel, it can be assumed that the collision can occur to any place in the collision area. However, sideways-on is considered leading the most severe damage to the leg than the other two orientations and stern-on will not be studied in this project.

3.3.4 Jacket Leg Model

The jacket leg length model is based on Kumang Cluster Platform as a reference for Malaysia's seas. The models use a diameter of 1 m and thickness of 0.0508 m and 0.015m while the length of the jacket leg is 6 m, the dimension of the jacket leg is kept same for every analysis after considered the dimension is sufficient to obtain required results.

A) Material Properties

The jacket leg is modelled using the same material model as the ship model only the density of the material is kept the same. The model is using an elastic/plastic isotropic with piecewise linear plasticity material, where the jacket leg is allowed to deform, dissipate impact energy and shows strain rate effects on the model. The material properties used for this model is presented in table 3.3.2.

Young's Module, E	2×10^{11} Pa
Yield Strength, σ_y	5.16×10^{8} Pa
Density, ρ	7850 kg/m^3
Poisson's Ratio, μ	0.3

Table 3.3.2: Jacket leg material properties.

B) Mesh and Elements

The general size of the elements of the vessel model is 0.3 m. The model is meshed in this way to see the important structure deformation characteristics.

C) Boundary conditions

The jacket leg is analyse using fixed in both end where the jacket end are considered fixed in all rotational degrees of freedom and all translational degrees of freedom except in the local axial direction of the jacket to be able to capture the deformation results. Hence, linear elastic is used.

D) Impact location

Normally the collision incidents take place around the water line of the fixed platform legs. Therefore it is estimated the impact location is between the middle of the jacket leg.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

Extensive of research has been carried out on ship-platform collision, the concerns for ship collision can be found in various design codes. This chapter discuss the quantitative data of data analysis and shows the damage pattern on the jacket leg due to the vessel impacts based on the simulation of ANSYS. By modelling a simple model, a different level of damage can be shown to relate the qualitative data gathered from the available recorded data of HSE, 2003.

4.2 DATA ANALYSIS AND RISK PREDICTION

A more detailed analysis of accidents and events has been performed based on the Ship-Platform Collision incident Database, HSE, 2003. This project use this as reference as it is one of the most reliable and most complete database of incidents in the offshore oil and gas sector. However the database only provides a good basis for lesson learning, it does not consists a good basis for statistical damage severity analysis. The database is based on the information collected and compiled by HSE at the request of the Offshore Division.

According to HSE, 2003, there are three type of vessel classification. Firstly, the “passing vessel” which is vessel should not have contravened the safety zone. Second vessel classification is “attendant vessel” which types of vessel working in and out of the safety zone. And lastly the “unspecified vessel”, this type vessel either does not been reported or unknown vessels that cause the damage without notice.

From the available recorded data (figure 4.2.0), it is safe to assume that attendant vessel resulted more collision with the platform than passing vessels as it works around the platform. From overall total of 557 collision incident, attendant vessel has a total of 514 collision incident. As the attendant vessels have higher trends than other vessels, it is specifically analysed. Thus, the chart from figure 4.2.1 below show specific type of attendant vessel causes the incident.

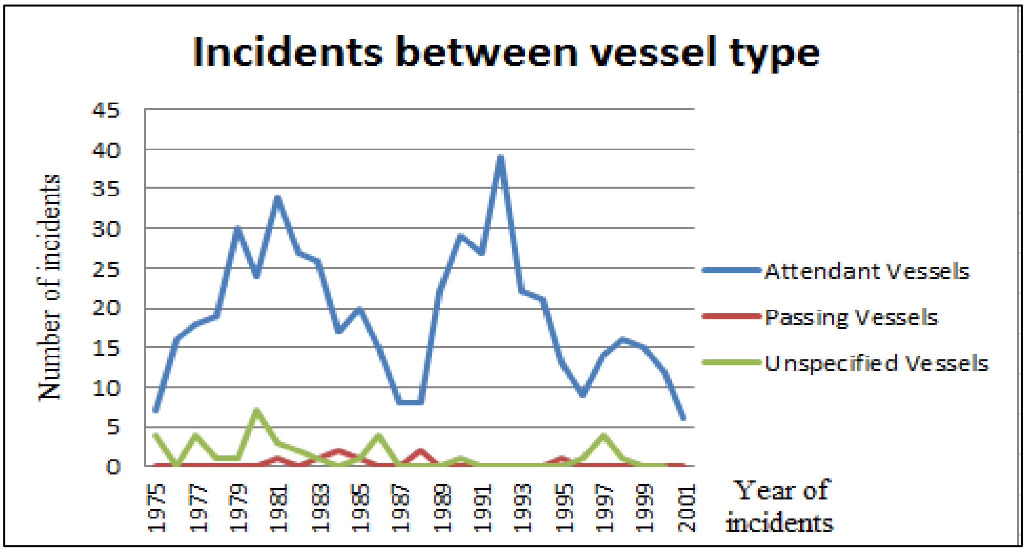

Figure 4.2.0: Comparison between vessel types.

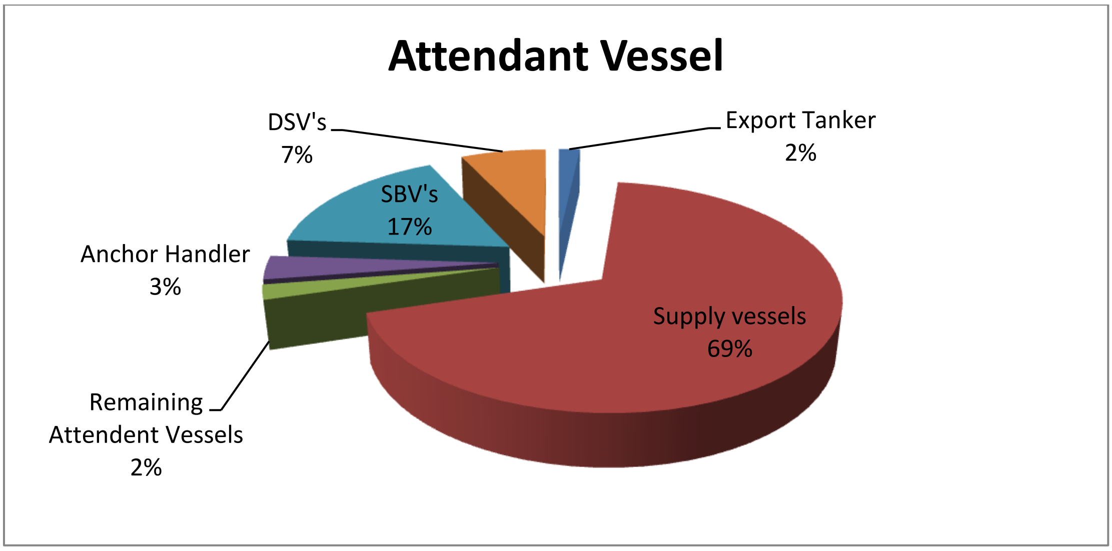

Figure 4.2.1: Specific vessel type of attendant vessel

It is understandable that supply vessel has higher incident frequencies than other attendant vessel by 353 incidents as supply vessel working in the vicinity of the platform more often than other attendant vessel such as transporting and provides services to the platform.

From figure 4.2.2, in 1981, the incident frequency reported seems to rise to the peak before declining abruptly till 1987. However, the incident increases steadily until 1992 before declining again. The increased of incident frequency from 1987 till1992 is probably due to the increase of mobile rig utilisation. Through the average, all incident frequency has fluctuated over the period.

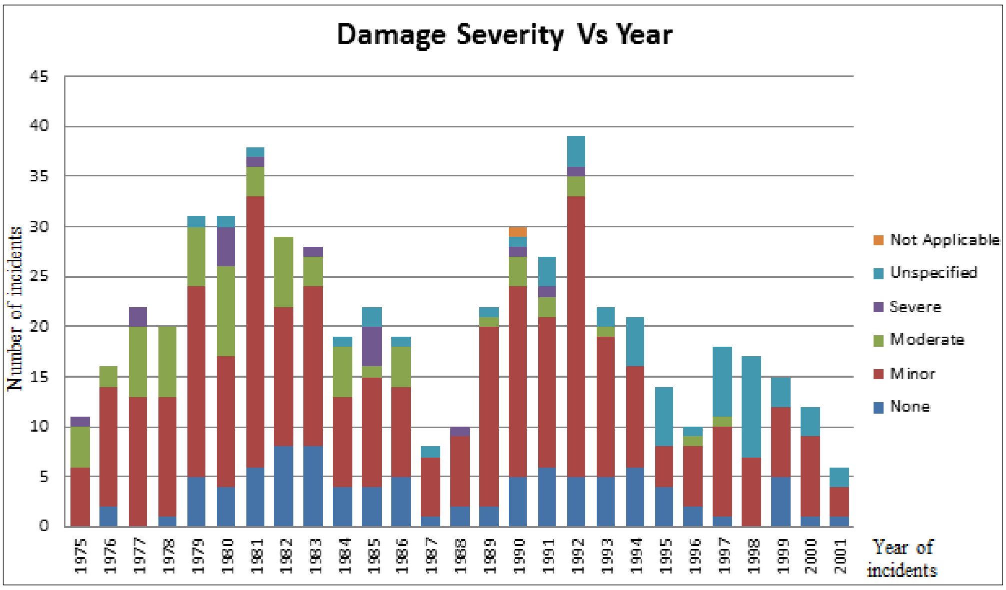

Figure 4.2.2: Damage severity throughout the years.

From the existing data, all reported incidents are separated and then classified its damage severity based on the time for fixing the damage of the platform to show any trends that might exist. Majority of minor damage with a total of 322 incidents have been reported, second highest is none damage with 93 incident, 69 incidents were classed as moderate, 17 incidents as severe and the rest is believed either to be in minor or none damage class.

Based on the reported damage and the severity of the member involved, the damage class can be identified as:

Severe: Where the damage is affecting the integrity of the platform and requires immediate repair. The repair can be up to one month, and if the information of the damage is insufficient, the affecting member will be considered as severe.

Moderate: The repair duration takes up to six month or longer depending on the damage.

Minor: The damage does not affecting the integrity of the platform.

None: No damage was sustained.

Unspecified: An incident believed to take place but there are no specified reports.

Not applicable: Report of incident which was not applicable to installation's structure.

Majority of incidents reported the weather was the prime cause of the incident resulting in minor damage or no damage at all towards the platform due to the large wave. However, most severe incidents that happen occurred in comparatively calm seas. Accidents which has been reported to have been caused by the weather most likely lead to minor or none damage at all.

The supply vessels at present under construction are mostly greater than 3,000 tonnes displacement. The 95% of the supply vessels quoted by DnV of 5,000 tonnes appears to be reasonable. There is a variation on size of the supply vessel, it depends on the locations of the sea. Accidents cause by bigger size of vessel most likely to cause severe to moderate damage.

The classification damage presented in the database is based on the duration of fixing the member affected. Thus, from the model simulation the damage associated with structural deformation will be used to identify the damage severity classification.

4.3 NUMERICAL MODELLING OF SHIP-PLATFORM IMPACT

A simulation of the jacket leg subjected to vessel collisions is performed and studied. The impact velocities and the weight of the vessel model are varied. Thus, the discussion will mainly focus on the damage pattern due to different variable.

The damage severity-pattern relationship was compared with the numerical simulation results. To improve computation efficiency and reducing simulation time, the rigid vessel model was adopted.

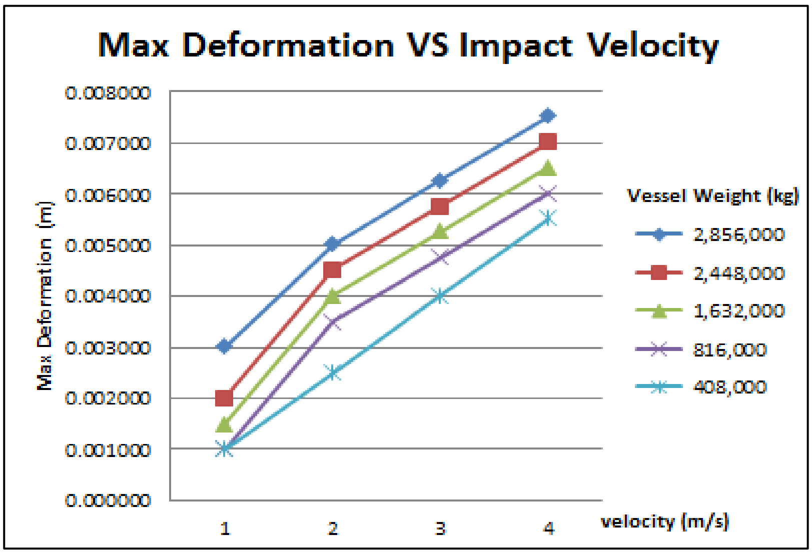

Figure 4.3.0: Deformation of jacket leg (thickness 15mm) with the relationship of weight and velocities.

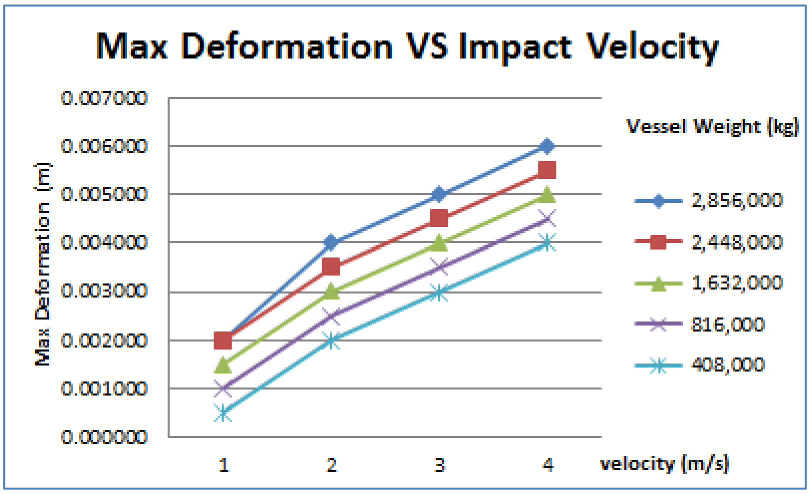

Figure 4.3.1: Deformation of jacket leg (thickness 50 mm) with the relationship of weight and velocities.

Due to the limitation of the ANSYS, the vessel model cannot be model exactly as a real ship dimension. It is expected if the actual size of the offshore supply vessels hits the jacket leg, a higher deformation and damage pattern will be more visible. However, the simulation results still satisfied this project objective by illustrated the relationship of maximum deformation of jacket leg is higher when impacted with more rigid vessel as shown in figure 4.3.2.

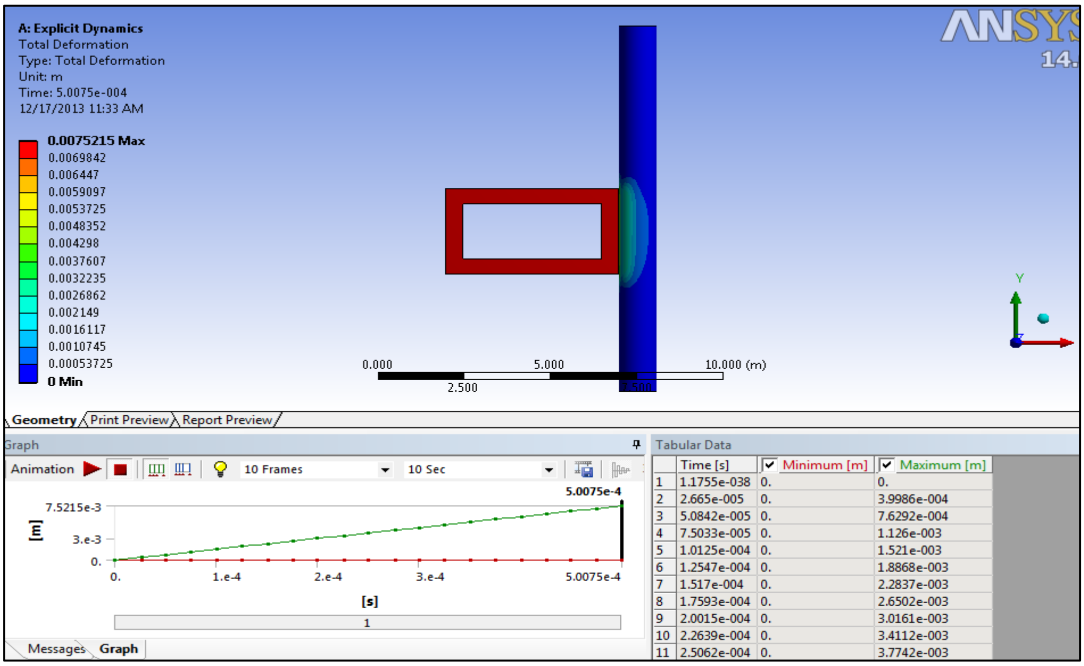

Figure 4.3.2: A simulation of vessel side-on model show deformation due to the impact.

The thickness of the jacket leg show insignificant difference in maximum deformation on the jacket leg. When the thickness of the jacket leg is 50 mm, the jacket leg showed deformation as shown in figure. However, a discrepancy appeared when comparing the thickness of jacket leg. The 50 mm thickness of jacket leg show more sturdiness when impacted by the vessel compared to the jacket leg 15 mm in thickness. Therefore, energy dissipation such that a much greater collision force would be required to produce a large impact energy affecting the jacket leg. Thus, the gradient of maximum deformation with a relationship of velocity and weight of a vessel tended to rise and likely threaten the integrity of a platform.

From figure 4.3.0 to 4.3.1, the velocities of vessel impact also play an important part in impact deformation relationship. Even though the velocity is low as the vessel impact is probably due to the weather condition or mechanical malfunction, the amount of damage caused to the platform is bigger.

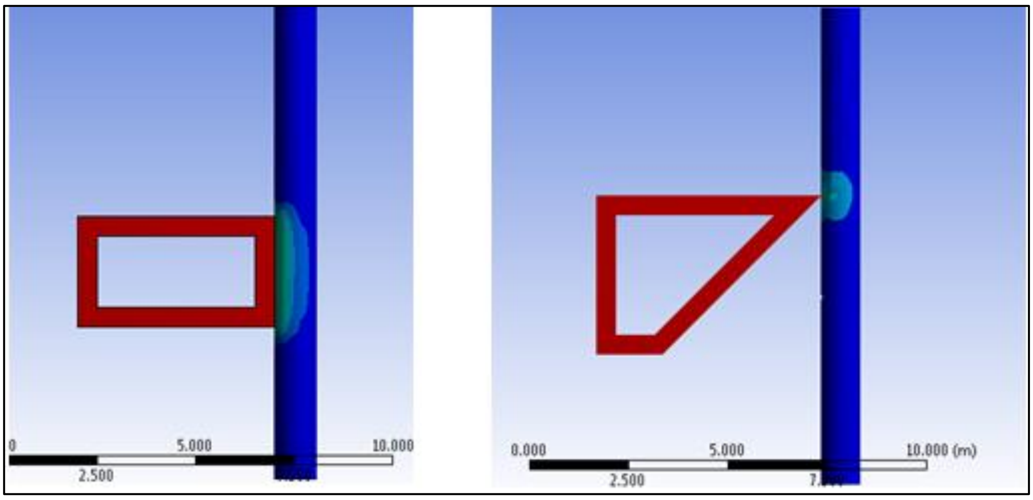

Figure 4.3.3: A head-on collision (right) and a side-on collision (left) show different approach of ship collision.

The orientation of the vessel (figure 4.3.3) in a collision is important as it has difference in terms of stiffness and strength of a vessel's bow, stern or side. With the influence of added mass and the collision velocity, the amount of damage caused to platform jacket is increased. With the same vessel weight and velocities impact of side-on collision, simulation of head-on is done and the result as shown in the figure 4.3.4.

The simulation show obvious result of head-on collision impact towards the jacket leg cause bigger deformation than side-on collision. A head-on collision gives a more concentrated force than a sideways impact and results in a larger amount of energy absorption for a given mass and velocity of the vessel. This might due to the characteristic dimension of the vessel therefore the energy dissipation is much larger than flat surface (side-on).

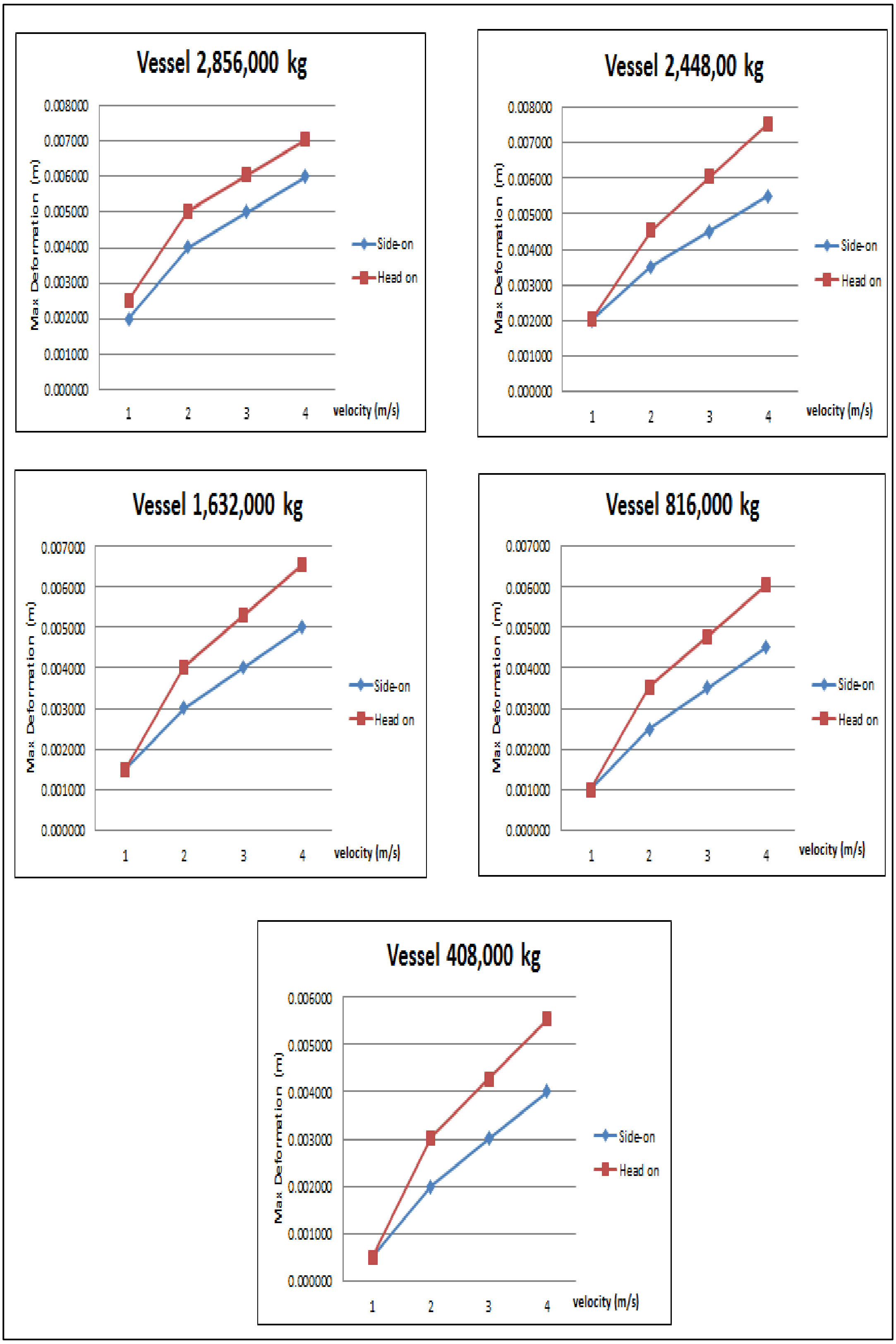

Figure 4.3.4: Comparison between collision impact of head-on and side-on of the vessel to the jacket leg.

4.4 CONCLUDING REMARKS

The database from HSE, 2003 is used as references for this project as it is the most complete recorded data for ship-platform collision. However, it can only be used as lesson learning as it does not include basis for damage severity classification. From the database, it can conclude that attendant vessel cause most of the incident frequency. And supply vessel can be extract out from the attendant vessel type as one contributing most of the incidents as it transport and provides support to the platform. Minor damage has the highest frequency events compared to the other damage classes.

Bad weather condition is reported causing minor or none damage to the platform but contradicting with severe damage where the sea environment is calm when the incident happens and most of the reported incident does not report the weather condition. Thus weather parameter is put aside. The severity damage is based on the repair duration of the damage member, there are no specific numbers showing the damage classification. Therefore, a simulation is conducted to provide reference for the damage severity.

According to DnV, the bigger the size of the ship the higher damage it can cause to the structure, and this is proven with the ANSYS simulation by increasing the weight of the vessel model the deformation on the jacket leg is higher. The impact velocities of the model vessel showed higher deformation can be made if the velocities of the vessel hitting the jacket leg increased.

Two orientation of vessel hitting the jacket leg at the same point is studied and showed the head-on collision caused higher damage to the jacket leg compare to the side-on collision due to the dimension characteristics of head-on.

Due to the limitation of the ANSYS, a real dimension of a real model cannot be made thus limiting this project to find the severity damage classification. Thus, further studies need to be done using different software to achieve the classification damage severity objective.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The purpose of this project was to clarify the definition of the severity damage of the collision between vessels and jacket leg. Analyses of collision frequency between the vessels from the database of HSE have been studied. The result from the simulation have been analyse and compared.

From data analysis, it can be concluded that the highest frequency of accident reported is minor accident. The database has been sorted the accident involving passing vessels and attendant vessels. And from that database it was found out that attendant vessel has the highest frequency of incident and the type of vessel from the attendant vessel category that has the highest rate of accident is supply vessel as it regularly working around the platform for transporting and providing services. Even though from the whole period of 1975 till 2001 severe damage class has the lowest rate of incident, nonetheless the potential of major structural damage or even catastrophic event still exists.

In the simulation result showed that added weight and velocities of the vessel play important part in obtaining the deformation results, the deformation is increasing with the increased weight and velocities. The thicker the jacket leg diameter the lower deformation can be made by the impact vessel. It can be considered as strong enough to withstand the collision forces compared to the thin layer jacket leg thickness, thus, a larger thickness is favourable.

The head-on and side-on impacts of the jacket leg also have been considered in this project to study if the contact area of a vessel is crucial or not to the jacket leg response. From the simulation, the result showed that the strength of side-on is lower that the head-on collision. Thus, the head-on impacts are most critical with the added mass and velocities of the vessel. However, the deformation from the simulation is not enough to understand the behaviour of the impact towards the jacket leg scenarios neither to classify the damage pattern from the existing database.

As a general conclusion, this project shows that the need for accurate finite element analyses in the collision impact parameter such as the sizing and the mass of a real vessel hitting the jacket leg to acquire true simulation deformation. This is because the database from HSE in terms of the damage severity is only qualitative data. This project wanted to see the real damage impact to be able to classify the damage severity in terms of quantitative results. However, due to the limitation of the ANSYS simulation, the result cannot be obtained. Thus further studies need to be done by using other software.

5.2 RECOMMENDATION

1. For the future significant work, collision incident data should be continued collected that may be used to support collision models and perform additional validation from other available recorded data.

2. Develop and include a simplified deformable bow model in the simulation and include its characteristics to assess the impact of the vessel and studied the changes the collision damage reading if available.

3. Use other software than ANSYS to compare the result of the same simulation with the same characteristic as ANSYS used.

4. Include the stern vessel orientation in the collision in the future studies to compare the damage result from the simulation with the theory of the expert.

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